First Part and Second Part – '862 Patent

'862 Claim 13: First Part and Second Part

13. A method of processing multiple wavelengths of light, the method comprising:

…dividing at least a portion of the optical signal communicated for processing into at least a first part and a second part, wherein the first part comprises an amplitude that is different than an amplitude of the second part

'862 Claim 13: First Part and Second Part

Cheetah's Construction	Defendants' Construction
Dividing a portion of the optical signal from the separating step* into at least two parts, where two of the parts have unequal amplitudes	**"dividing the input '*optical signal*' into first and second copies with different amplitudes"**

* Cheetah has abandoned this aspect of its construction, conceding that the input to the "dividing" step is the input "optical signal communicated for processing."

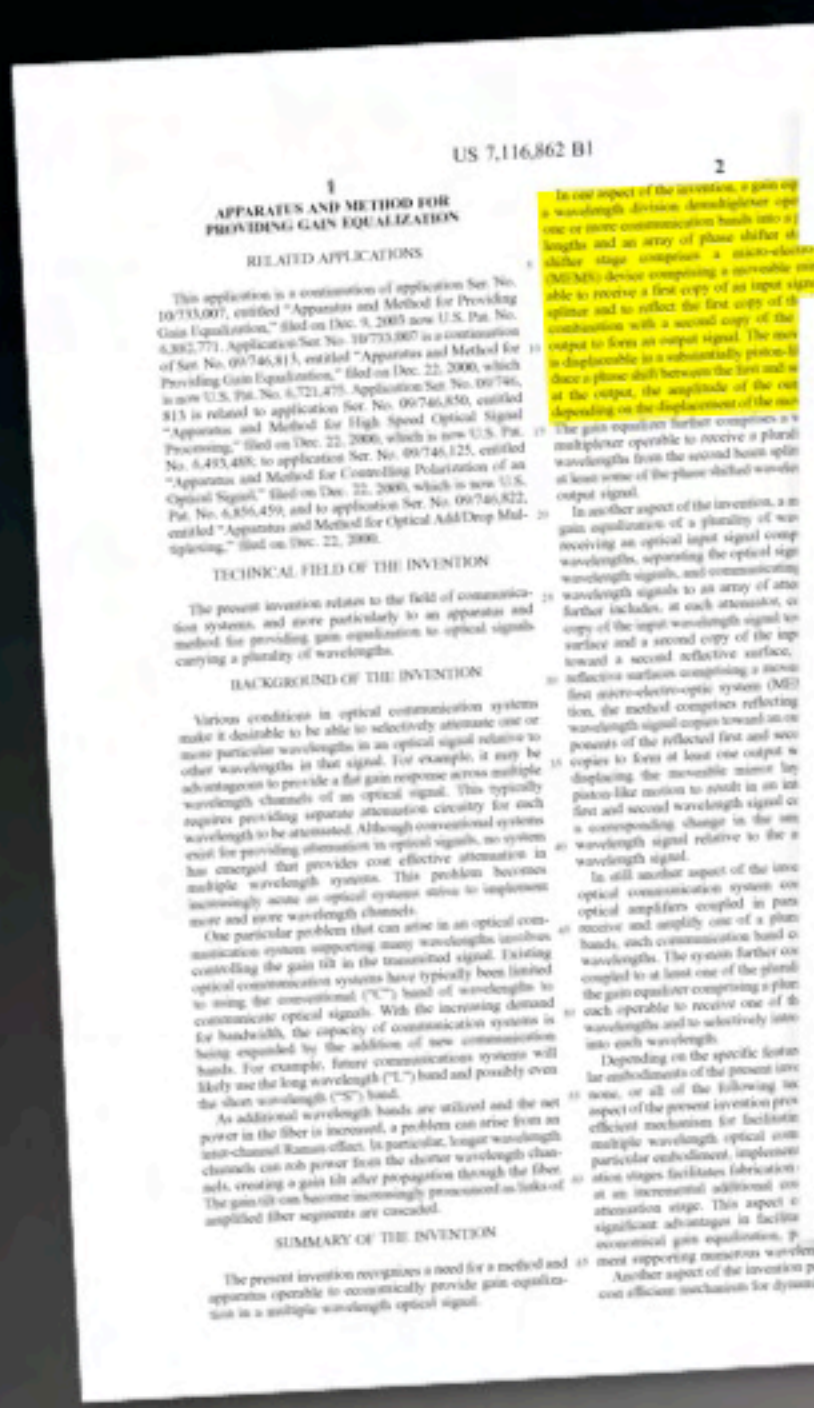
Cheetah's Construction is No Construction

Claim Term	Cheetah's Construction
Dividing at least a portion of the optical signal communicated for processing into at least a first part and a second part, wherein the first part comprises an amplitude that is different than an amplitude of the second part	Dividing a portion of the optical signal from the separating step* into at least two parts, where two of the parts have unequal amplitudes

➡ **Cheetah offers no definition or construction of "part"**

* Cheetah has abandoned this aspect of its construction, conceding that the input to the "dividing" step is the input "optical signal communicated for processing."

The Summary of the Invention Specifies that the Signal is Divided into "Copies"


US 7,116,862 B1

1

APPARATUS AND METHOD FOR PROVIDING GAIN EQUALIZATION

RELATED APPLICATIONS

This application is a continuation of application Ser. No. 10/733,007, entitled "Apparatus and Method for Providing Gain Equalization," filed on Dec. 9, 2003 now U.S. Pat. No. 6,882,771. Application Ser. No. 10/733,007 is a continuation of Ser. No. 09/746,813, entitled "Apparatus and Method for Providing Gain Equalization," filed on Dec. 22, 2000, which is now U.S. Pat. No. 6,721,475. Application Ser. No. 09/746,813 is related to application Ser. No. 09/746,850, entitled "Apparatus and Method for High Speed Optical Signal Processing," filed on Dec. 22, 2000, which is now U.S. Pat. No. 6,493,488; to application Ser. No. 09/746,125, entitled "Apparatus and Method for Controlling Polarization of an Optical Signal," filed on Dec. 22, 2000, which is now U.S. Pat. No. 6,856,459; and to application Ser. No. 09/746,822, entitled "Apparatus and Method for Optical Add/Drop Multiplexing," filed on Dec. 22, 2000.

TECHNICAL FIELD OF THE INVENTION

The present invention relates to the field of communication systems, and more particularly to an apparatus and method for providing gain equalization to optical signals carrying a plurality of wavelengths.

BACKGROUND OF THE INVENTION

Various conditions in optical communication systems make it desirable to be able to selectively attenuate one or more particular wavelengths in an optical signal relative to other wavelengths in that signal. For example, it may be advantageous to provide a flat gain response across multiple wavelength channels of an optical signal. This typically requires providing separate attenuation circuitry for each wavelength to be attenuated. Although conventional systems exist for providing attenuation in optical signals, no system has emerged that provides cost effective attenuation in multiple wavelength systems. This problem becomes increasingly acute as optical systems strive to implement more and more wavelength channels.

One particular problem that can arise in an optical communication system supporting many wavelengths involves controlling the gain tilt in the transmitted signal. Existing optical communication systems have typically been limited to using the conventional ("C") band of wavelengths to communicate optical signals. With the increasing demand for bandwidth, the capacity of communication systems is being expanded by the addition of new communication bands. For example, future communications systems will likely use the long wavelength ("L") band and possibly even the short wavelength ("S") band.

As additional wavelength bands are utilized and the net power in the fiber is increased, a problem can arise from an inter-channel Raman effect. In particular, longer wavelength channels can rob power from the shorter wavelength channels, creating a gain tilt after propagation through the fiber. The gain tilt can become increasingly pronounced as links of amplified fiber segments are cascaded.

SUMMARY OF THE INVENTION

The present invention recognizes a need for a method and apparatus operable to economically provide gain equalization in a multiple wavelength optical signal.

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In one aspect of the invention, a gain equalizer comprises a wavelength division demultiplexer operable to separate one or more communication bands into a plurality of wavelengths and an array of phase shifter stages. Each phase shifter stage comprises a micro-electro-optic system (MEMS) device comprising a moveable mirror layer operable to receive a first copy of an input signal from a beam splitter and to reflect the first copy of the input signal for combination with a second copy of the input signal at an output to form an output signal. The moveable mirror layer is displaceable in a substantially piston-like motion to introduce a phase shift between the first and second signal copies at the output, the amplitude of the output signal varying depending on the displacement of the moveable mirror layer. The gain equalizer further comprises a wavelength division multiplexer operable to receive a plurality of wavelengths from the second beam splitter and to combine at least some of the phase-shifted wavelengths to form an output signal.

In another aspect of the invention, a method for providing gain equalization of a plurality of wavelengths comprises receiving an optical input signal comprising a plurality of wavelengths, separating the optical signal into a plurality of wavelength signals, and communicating each of the plurality of wavelength signals to an array of attenuator stages. The method further includes, at each attenuator, creating a first copy of the input wavelength signal and directing the first copy toward a first reflective surface and a second copy of the input wavelength signal toward a second reflective surface, the first and second reflective surfaces comprising a moveable mirror layer of a first micro-electro-optic system (MEMS) device. In addition, the method comprises reflecting the first copy of the input wavelength signal toward an output and reflecting the second copy of the input wavelength signal toward an output, the first and second copies of the reflected first and second wavelength signals comprising copies to form at least one output wavelength signal. The method further includes displacing the moveable mirror layer of the first MEMS device in a substantially piston-like motion to result in an introduction of a phase shift between the first and second wavelength signal copies, the phase shift resulting in a corresponding change in the amplitude of the output wavelength signal relative to the amplitude of the input wavelength signal.

In still another aspect of the invention, a wavelength division multiplexed optical communication system comprises a plurality of optical amplifiers coupled in parallel, the optical amplifiers operable to receive and amplify one of a plurality of wavelength bands, each communication band comprising a plurality of wavelengths. The system further comprises a gain equalizer coupled to at least one of the plurality of optical amplifiers, the gain equalizer comprising a plurality of attenuator stages, each operable to receive one of the plurality of wavelengths and to selectively introduce attenuation into each wavelength.

Depending on the specific features of particular embodiments of the present invention, one, some, or all of the following technical advantages may be present. One aspect of the present invention provides an efficient mechanism for facilitating attenuation of multiple wavelength optical communication signals. In particular embodiment, implementation of the attenuation stages facilitates fabrication of the attenuator stages at an incremental additional cost per attenuation stage. This aspect of the invention provides significant advantages in facilitating economical gain equalization, particularly in an environment supporting numerous wavelengths.

Another aspect of the invention provides an effective and cost efficient mechanism for dynamically adjusting the gain

SUMMARY OF THE INVENTION

In one aspect of the invention, a gain equalizer comprises a wavelength division demultiplexer operable to separate one or more communication bands into a plurality of wavelengths and an array of phase shifter stages. Each phase shifter stage comprises a micro-electro-optic system (MEMS) device comprising a moveable mirror layer operable to receive a first copy of an input signal from a beam splitter and to reflect the first copy of the input signal for combination with a second copy of the input signal at an output to form an output signal. The moveable mirror layer is displaceable in a substantially piston-like motion to introduce a phase shift between the first and second signal copies at the output, the amplitude of the output signal varying depending on the displacement of the moveable mirror layer.

'862 Patent, col. 2 ll. 1-14.

Every Embodiment Requires the Creation of Copies

- Cheetah does not dispute this

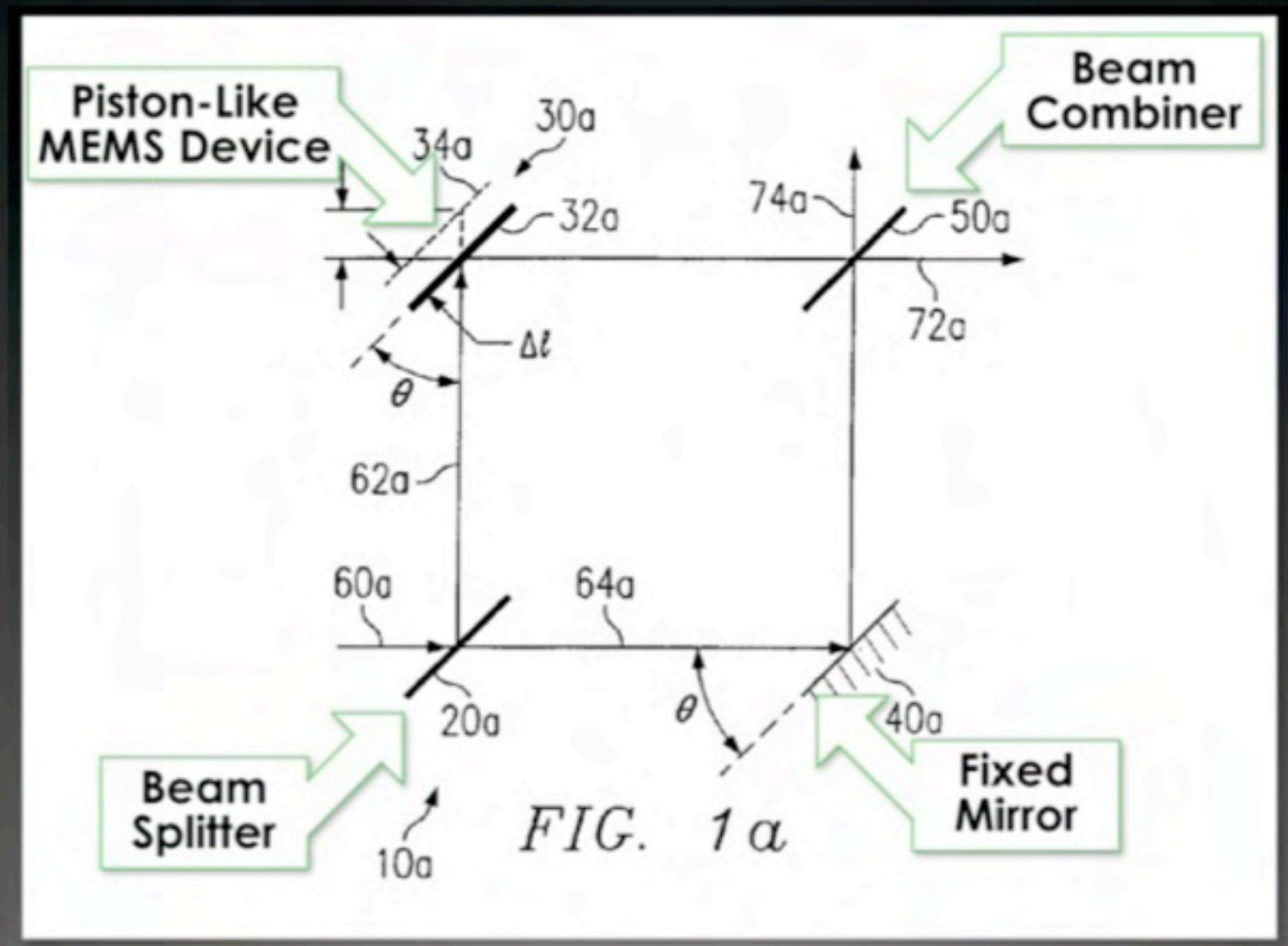


FIG. 1a

The Variable Attenuator Would Not Work Without Division Into Copies

Interference requires copies to come together

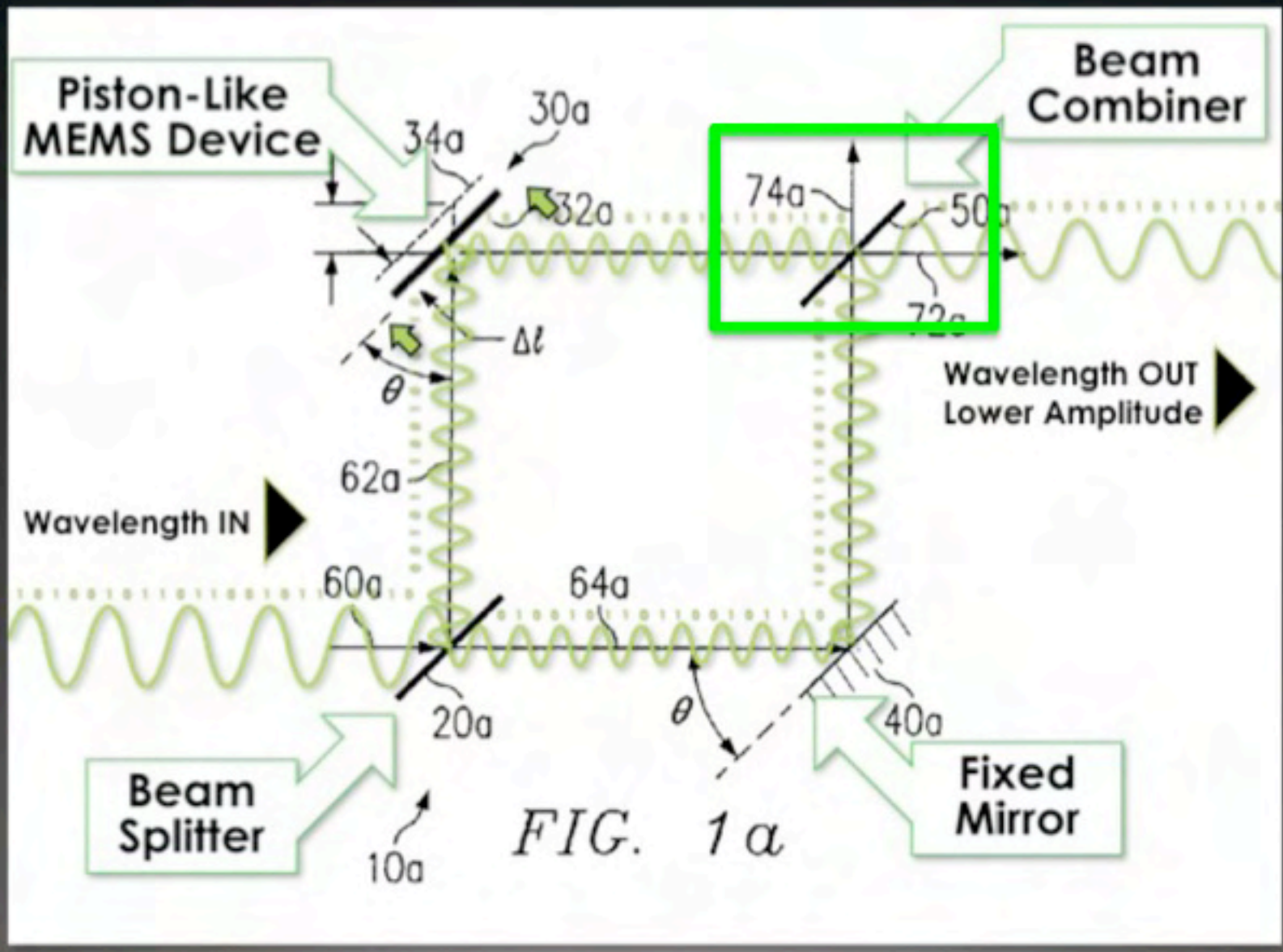


FIG. 1a

Figure 1a is a Building Block in the '862 patent

DETAILED DESCRIPTION OF THE INVENTION

I. Building Blocks for High Speed Optical Signal Processing

'862 Patent, col. 4 ll. 45.

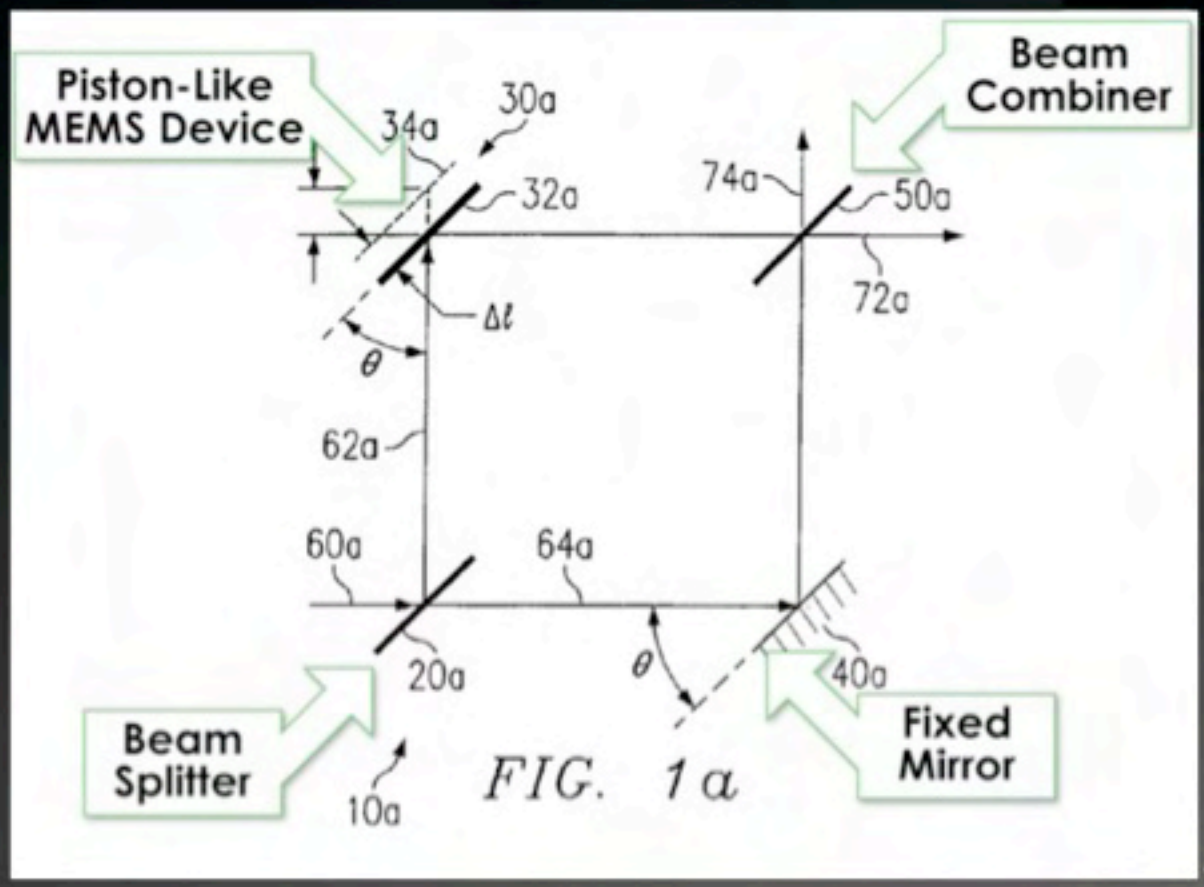
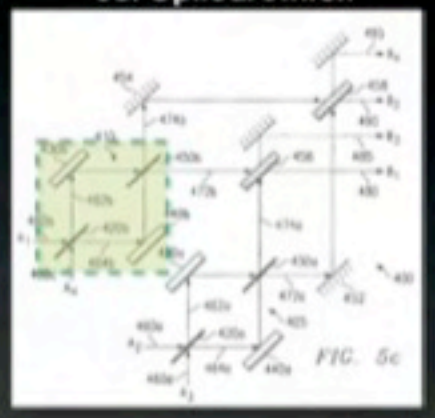
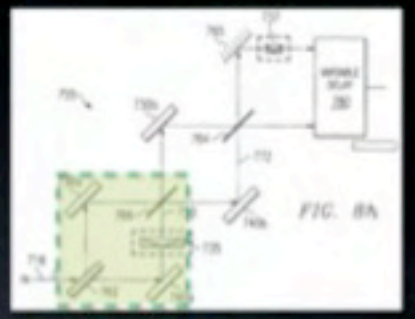


FIG. 1a

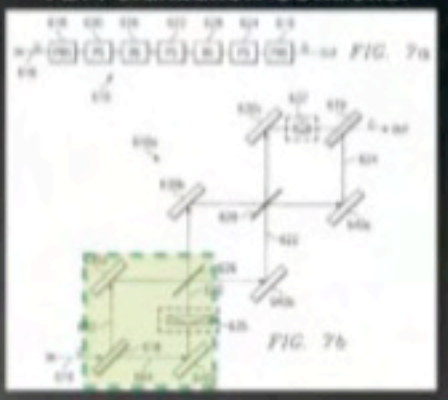
5c: Optical Switch



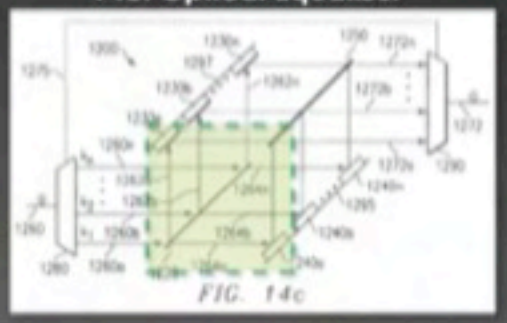
8h: Polarization Mode Compensator



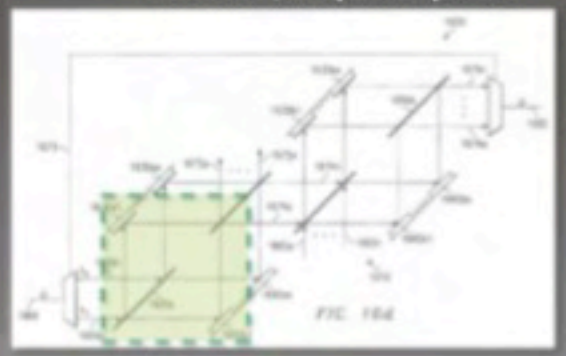
7b: Polarization Controller



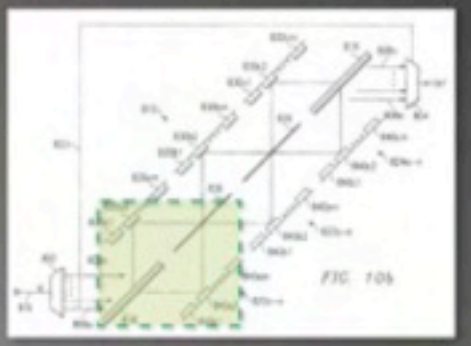
14c: Optical Equalizer



16d: Add/drop Multiplexer



10b: Polarization Controller Array



First Signal Part and Second Signal Part – ’714 Patent

'714 Patent: "First Signal Part"; "Second Signal Part"

18. A light processing system, comprising:

. . . an optical divider operable to receive an unmodulated optical signal and to separate the unmodulated optical signal into a first signal part and a second signal part . . .

'714 Patent: "First Signal Part"; "Second Signal Part"

19. A light processing one or more optical signals, the method comprising:

. . . separating an optical signal into a first signal part and a second signal part . . .

'714 Patent: "First Signal Part"; "Second Signal Part"

Cheetah's Construction	Defendants' Construction
To separate the optical signal into at least two parts, for example, into two or more wavelengths	**First and second copies of the** *"unmodulated optical signal"* **[Claim 18]** **First and second copies of the input** *"optical signal"* **[Claim 19]**

Cheetah's Construction Is No Construction

Claim Term	Cheetah's Construction
to separate the unmodulated optical signal into a first signal part and a second signal part . . .	To separate the optical signal into at least two parts, for example, into two or more wavelengths

Points of Agreement

- Parties agree that Figure 15 shows the only embodiment purportedly claimed by claims 18 and 19
- Parties agree that Figure 15 shows separating into "copies"

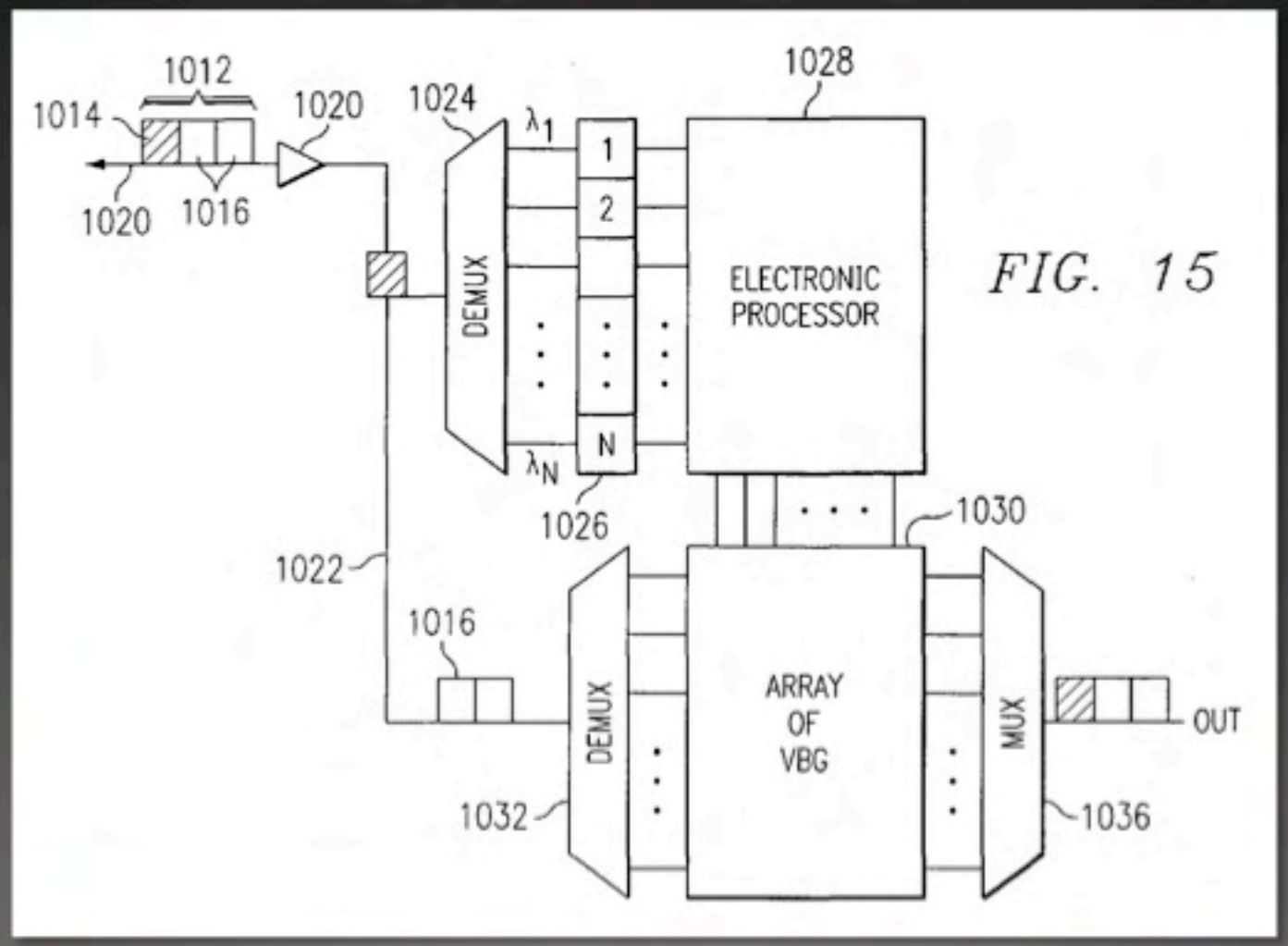


FIG. 15

Relevant Figure

Second Part

Divider/Tap

First Part

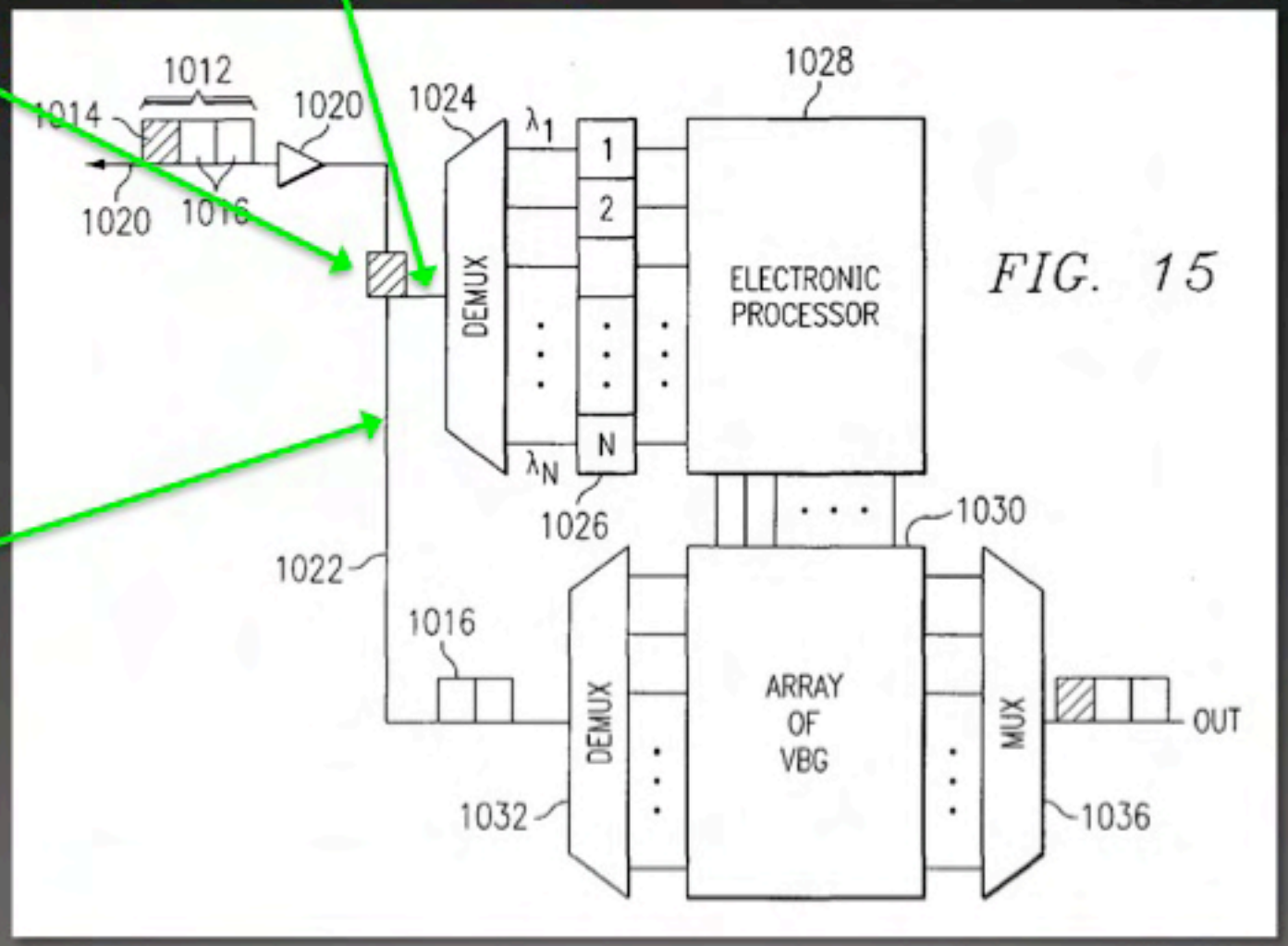


FIG. 15

Relevant Figure

Fiber optic tap **1018** receives optical signals **1012** and sends one copy of the signal including at least header information **1014** to demultiplexer **1024**, and sends another copy of the signal including at least payload information **1016** to delay line **1022**.

'714 Patent col. 21 ll. 6-10.

Second Part

Divider/Tap

First Part

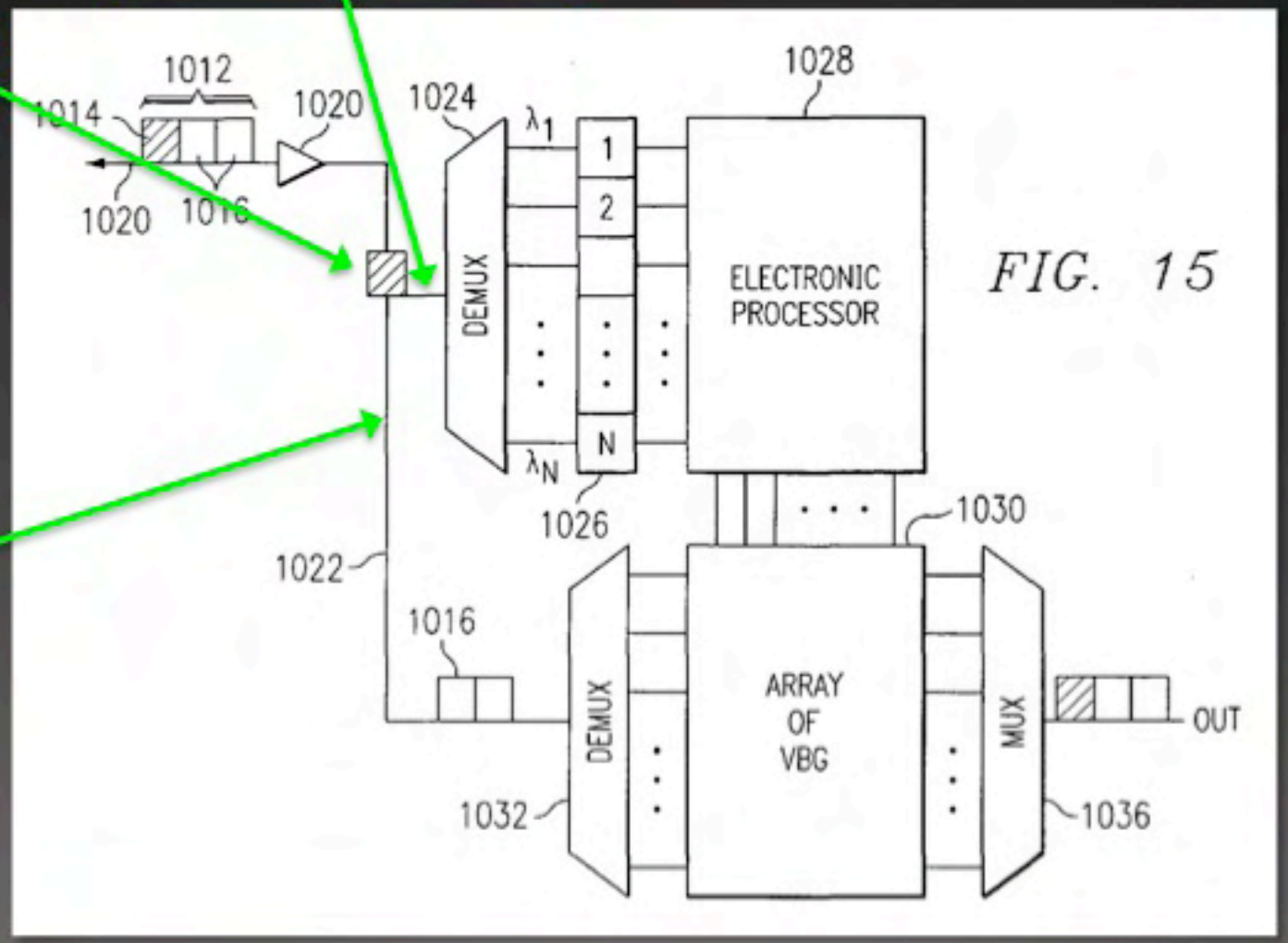


FIG. 15

The Parties' Positions

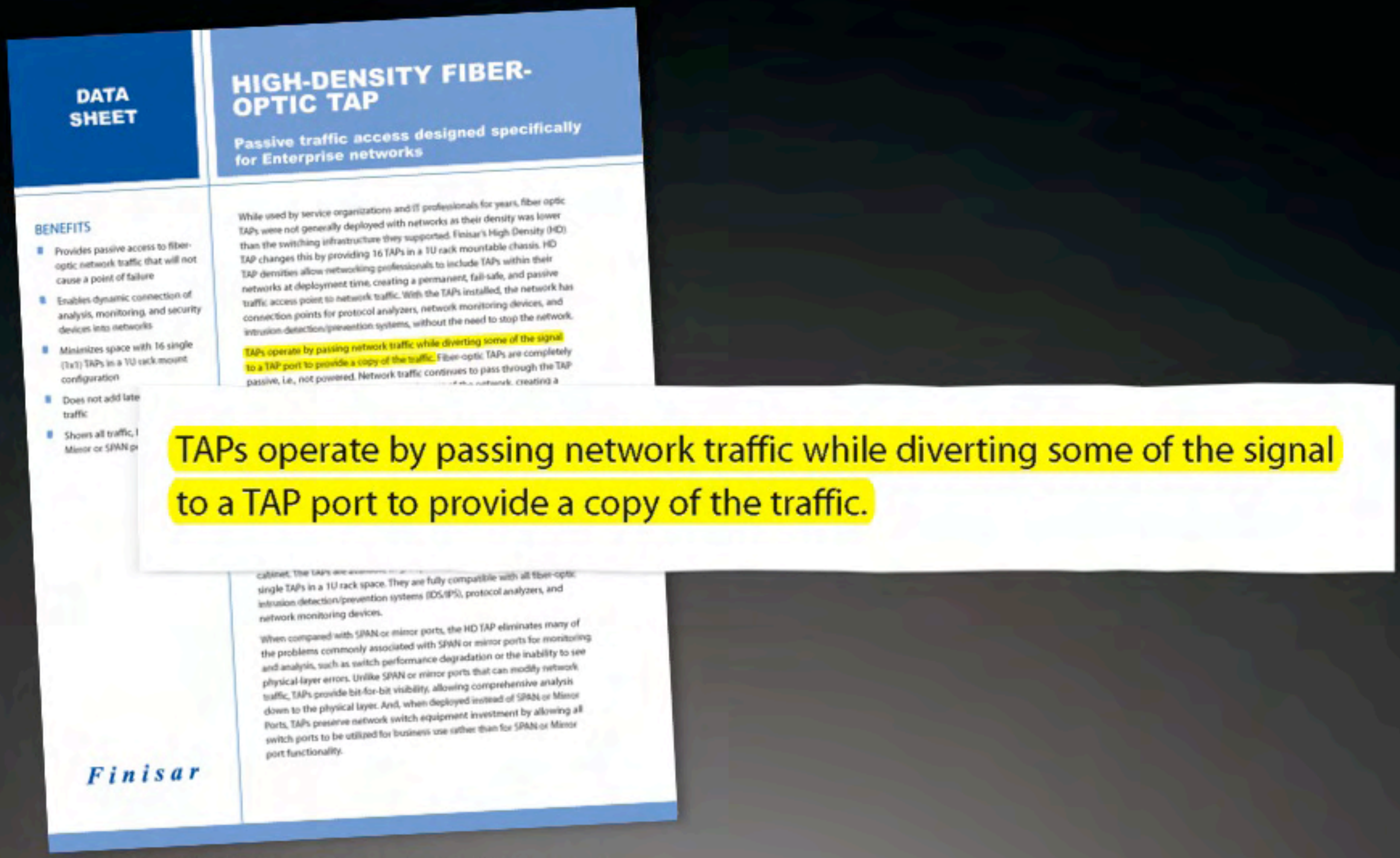
➡ **Defendants:** "Copy" means "Copy"

Cheetah: "[T]he '714 specification uses the term 'copy' loosely to refer to things that are portions of a whole, not 'copies' of one another in the conventional sense." Reply Br. at 10.

Cheetah's Construction Cannot Be Supported

- The specification does not indicate a special meaning for the word "copy."
- The structure making the copies in Figure 15 is a fiber optic tap, which simply taps part of the signal and is not capable of generating anything other than copies.
- The patent does not support a first separating step that separates by wavelengths (Cheetah's construction)
- The specification does not say that the copy with header information and the copy with payload information could be different from one another.

Cheetah's Construction Cannot Be Supported


DATA SHEET

HIGH-DENSITY FIBER-OPTIC TAP

Passive traffic access designed specifically for Enterprise networks

BENEFITS

- Provides passive access to fiber-optic network traffic that will not cause a point of failure
- Enables dynamic connection of analysis, monitoring, and security devices into networks
- Minimizes space with 16 single (1x1) TAPs in a 1U rack mount configuration
- Does not add late traffic
- Shows all traffic, Mirror or SPAN p

While used by service organizations and IT professionals for years, fiber optic TAPs were not generally deployed with networks as their density was lower than the switching infrastructure they supported. Finisar's High Density (HD) TAP changes this by providing 16 TAPs in a 1U rack mountable chassis. HD TAP densities allow networking professionals to include TAPs within their networks at deployment time, creating a permanent, fail-safe, and passive traffic access point to network traffic. With the TAPs installed, the network has connection points for protocol analyzers, network monitoring devices, and intrusion detection/prevention systems, without the need to stop the network.

TAPs operate by passing network traffic while diverting some of the signal to a TAP port to provide a copy of the traffic. Fiber-optic TAPs are completely passive, i.e., not powered. Network traffic continues to pass through the TAP

cabinet. The TAPs are

single TAPs in a 1U rack space. They are fully compatible with all fiber-optic intrusion detection/prevention systems (IDS/IPS), protocol analyzers, and network monitoring devices.

When compared with SPAN or mirror ports, the HD TAP eliminates many of the problems commonly associated with SPAN or mirror ports for monitoring and analysis, such as switch performance degradation or the inability to see physical-layer errors. Unlike SPAN or mirror ports that can modify network traffic, TAPs provide bit-for-bit visibility, allowing comprehensive analysis down to the physical layer. And, when deployed instead of SPAN or Mirror Ports, TAPs preserve network switch equipment investment by allowing all switch ports to be utilized for business use rather than for SPAN or Mirror port functionality.

Finisar

TAPs operate by passing network traffic while diverting some of the signal to a TAP port to provide a copy of the traffic.

Finisar Tap Data Sheet, available at www.finisar.com/download_dFJP1jHd_tap5_22_07.pdf

Moveable Mirror

'862 Claim 14: The Moveable Mirror Limitation

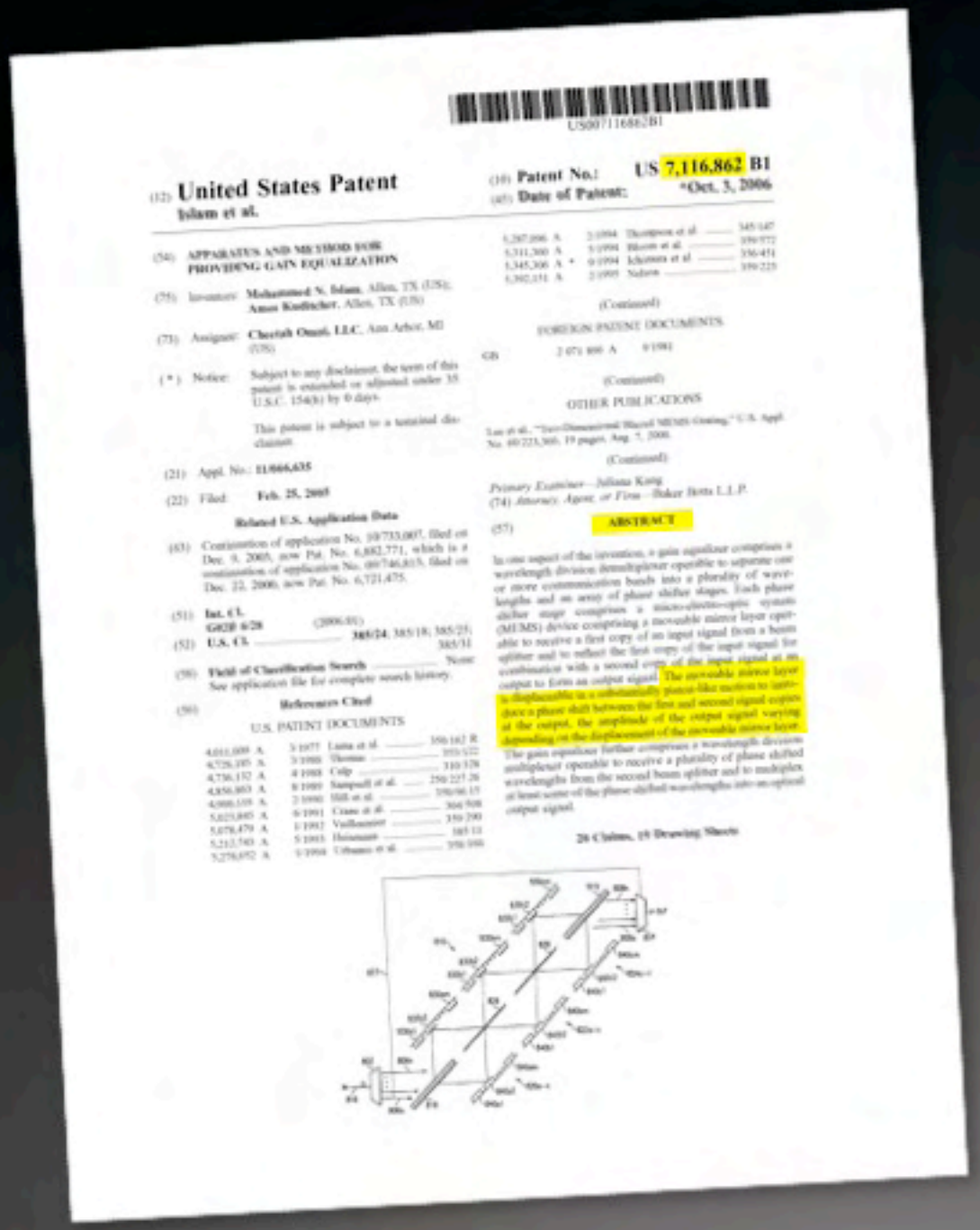
14. The method of claim 13…

wherein the moveable mirror is operable to move relative to the inner conductive layer in response to a voltage difference between the moveable mirror and the inner conductive layer.

’862 Patent Claim 14: The Moveable Mirror Limitation

Cheetah’s Construction	Defendants’ Construction
When the voltage between the moveable mirror and the inner conductive layer changes, the moveable mirror moves relative to the inner conductive layer.	The mirror is operable to be displaced in an approximately parallel plane to the previous mirror position.

The Movement of the '862 "Moveable Mirror" is Substantially "Piston-Like"



US007116862B1

(12) **United States Patent**
Islam et al.

(10) **Patent No.: US 7,116,862 B1**
(45) **Date of Patent: *Oct. 3, 2006**

(54) **APPARATUS AND METHOD FOR PROVIDING GAIN EQUALIZATION**

(75) Inventors: **Mohammed N. Islam**, Allen, TX (US); **Anas Kodticher**, Allen, TX (US)

(73) Assignee: **Cheetah Omni, LLC**, Ann Arbor, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/066,635**

(22) Filed: **Feb. 25, 2005**

Related U.S. Application Data

(63) Continuation of application No. 10/733,007, filed on Dec. 9, 2003, now Pat. No. 6,882,771, which is a continuation of application No. 09/746,815, filed on Dec. 22, 2000, now Pat. No. 6,721,475.

(51) **Int. Cl.**
G02B 6/28 (2006.01)

(52) **U.S. Cl.** **385/24**; 385/18; 385/25; 385/31

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

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(Continued)

Primary Examiner—Juliana Kang
(74) *Attorney, Agent, or Firm*—Baker Botts L.L.P.

(57) **ABSTRACT**

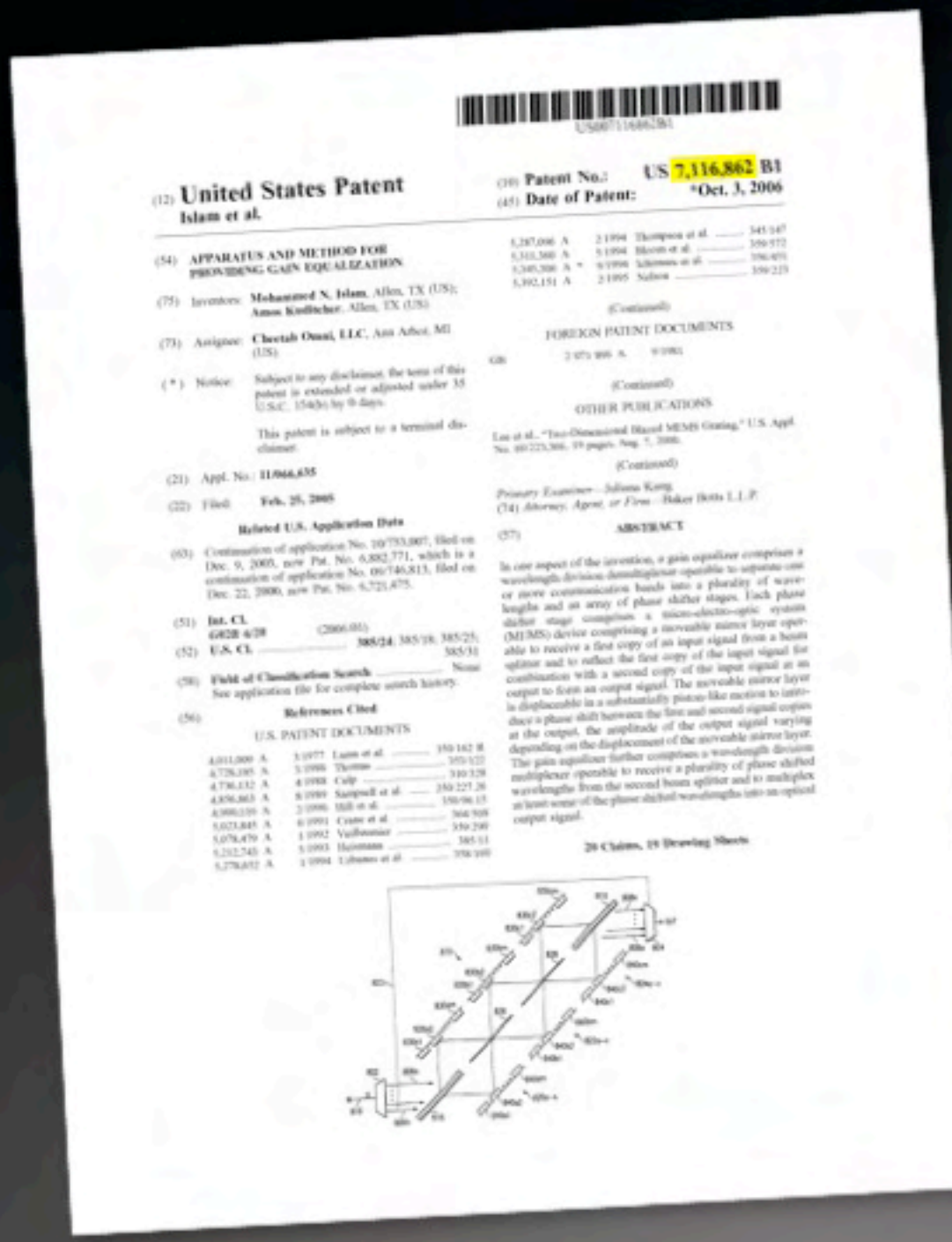
In one aspect of the invention, a gain equalizer comprises a wavelength division demultiplexer operable to separate one or more communication bands into a plurality of wavelengths and an array of phase shifter stages. Each phase shifter stage comprises a micro-electro-optic system (MEMS) device comprising a moveable mirror layer operable to receive a first copy of an input signal from a beam splitter and to reflect the first copy of the input signal for combination with a second copy of the input signal at an output to form an output signal. The moveable mirror layer is displaceable in a substantially piston-like motion to introduce a phase shift between the first and second signal copies at the output, the amplitude of the output signal varying depending on the displacement of the moveable mirror layer. The gain equalizer further comprises a wavelength division multiplexer operable to receive a plurality of phase shifted wavelengths from the second beam splitter and to multiplex at least some of the phase shifted wavelengths into an optical output signal.

26 Claims, 19 Drawing Sheets

(57) **ABSTRACT**

In one aspect of the invention, a gain equalizer comprises a wavelength division demultiplexer operable to separate one or more communication bands into a plurality of wavelengths and an array of phase shifter stages. Each phase shifter stage comprises a micro-electro-optic system (MEMS) device comprising a moveable mirror layer operable to receive a first copy of an input signal from a beam splitter and to reflect the first copy of the input signal for combination with a second copy of the input signal at an output to form an output signal. The moveable mirror layer is displaceable in a substantially piston-like motion to introduce a phase shift between the first and second signal copies at the output, the amplitude of the output signal varying depending on the displacement of the moveable mirror layer. The gain equalizer further comprises a wavelength division multiplexer operable to receive a plurality of phase shifted wavelengths from the second beam splitter and to multiplex at least some of the phase shifted wavelengths into an optical output signal.

"Piston-Like" Motion Means Displacement in an Approximately Parallel Plane



(12) **United States Patent**
Islam et al.

(10) **Patent No.: US 7,116,862 B1**
(45) **Date of Patent: *Oct. 3, 2006**

(54) **APPARATUS AND METHOD FOR PROVIDING GAIN EQUALIZATION**

(75) Inventors: **Mohammed N. Islam**, Allen, TX (US); **Amos Kiolbelcher**, Allen, TX (US)

(73) Assignee: **Cheetah Omni, LLC**, Ann Arbor, MI (US)

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(51) **Int. Cl.**
G02B 6/28 (2006.01)

(52) **U.S. Cl.** **385/24**; 385/18; 385/25; 385/31

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

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5,212,745	A	5/1993	Heinmann	385/11
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5,311,360	A	5/1994	Bloom et al.	359/572
5,345,308	A *	9/1994	Ichimura et al.	356/451
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Lee et al., "Two-Dimensional Blazed MEMS Grating," U.S. Appl. No. 60/225,306, 19 pages, Aug. 7, 2000.

(Continued)

Primary Examiner—Juliana Kang
(74) *Attorney, Agent, or Firm*—Baker Botts L.L.P.

(57) **ABSTRACT**

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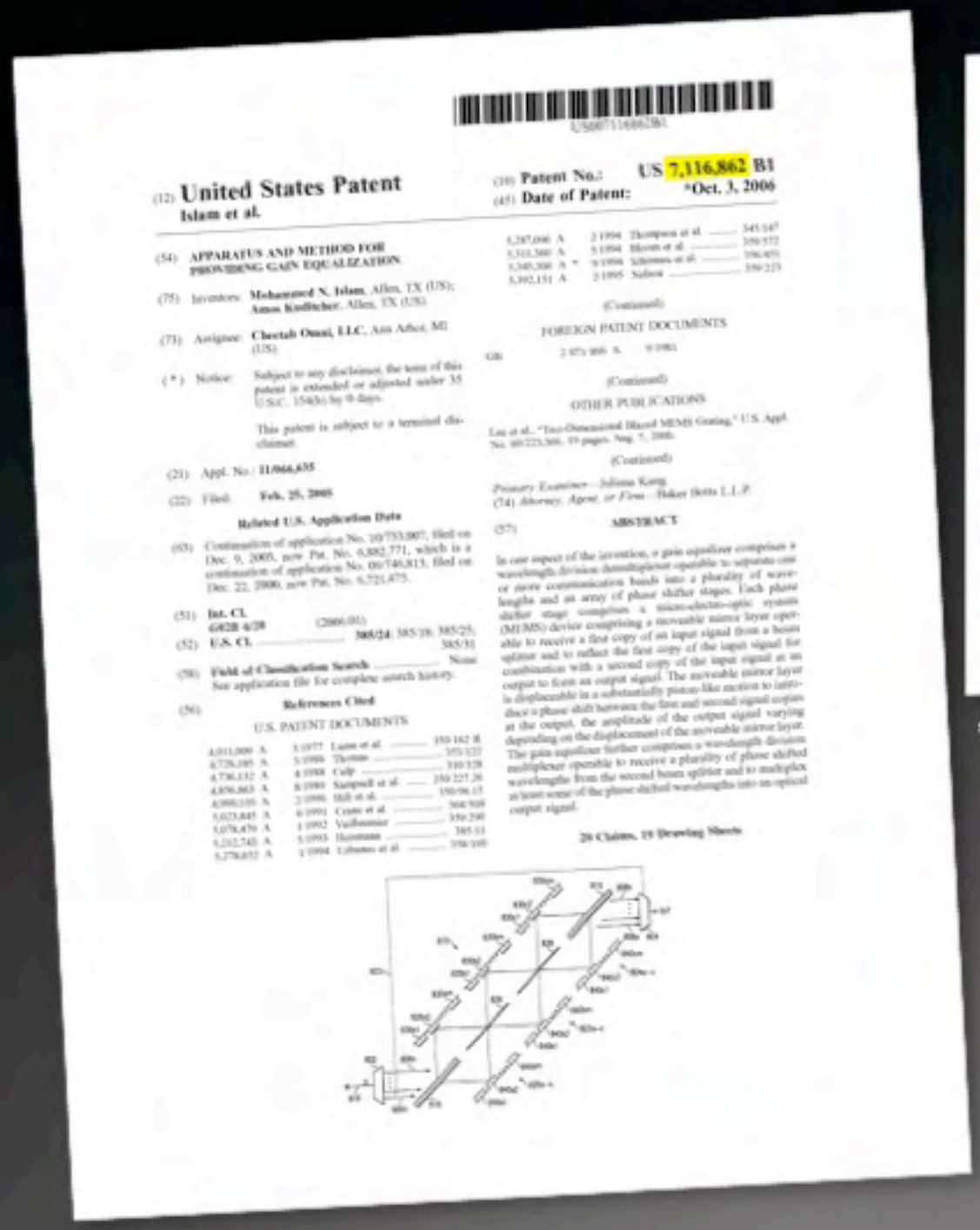
20 Claims, 19 Drawing Sheets

Throughout this document, the term "piston-like" motion refers to a motion in which the moveable mirror is intended to be displaced in an approximately parallel plane to the previous mirror position.

'862 Patent, col. 5 ll. 60-63.

Only "Piston-Like" Motion is Within the Scope of the '862 Invention



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(54) **APPARATUS AND METHOD FOR PROVIDING GAIN EQUALIZATION**

(75) Inventors: **Mohammed N. Islam**, Allen, TX (US); **Amos Kiolbelcher**, Allen, TX (US)

(73) Assignee: **Cheetah Omni, LLC**, Ann Arbor, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

(21) Appl. No.: **11/066,635**

(22) Filed: **Feb. 25, 2005**

Related U.S. Application Data

(63) Continuation of application No. 10/753,807, filed on Dec. 9, 2003, now Pat. No. 6,882,771, which is a continuation of application No. 09/740,813, filed on Dec. 22, 2000, now Pat. No. 6,721,475.

(51) **Int. Cl.**
G02B 6/28 (2006.01)

(52) **U.S. Cl.** **385/24**; 385/18; 385/25; 385/31

(58) **Field of Classification Search** ..... None
See application file for complete search history.

(56) **References Cited**

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5,078,479	A	1/1992	Vuilleumier	350/290
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5,345,200	A *	9/1994	Ichimura et al.	356/451
5,392,151	A	2/1995	Nelson	359/223

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Lee et al., "Two-Dimensional Blazed MEMS Grating," U.S. Appl. No. 60/225,300, 19 pages, Aug. 7, 2000.

(Continued)

Primary Examiner—Juliana Kang
(74) *Attorney, Agent, or Firm*—Baker Botts L.L.P.

(57) **ABSTRACT**

In one aspect of the invention, a gain equalizer comprises a wavelength division demultiplexer operable to separate one or more communication bands into a plurality of wavelengths and an array of phase shifter stages. Each phase shifter stage comprises a micro-electro-optic system (MEMS) device comprising a moveable mirror layer operable to receive a first copy of an input signal from a beam splitter and to reflect the first copy of the input signal for combination with a second copy of the input signal at an output to form an output signal. The moveable mirror layer is displaceable in a substantially piston-like motion to introduce a phase shift between the first and second signal copies at the output, the amplitude of the output signal varying depending on the displacement of the moveable mirror layer. The gain equalizer further comprises a wavelength division multiplexer operable to receive a plurality of phase shifted wavelengths from the second beam splitter and to multiplex at least some of the phase shifted wavelengths into an optical output signal.

20 Claims, 19 Drawing Sheets

In practice, for various reasons, physical embodiments of the invention may not exhibit true "piston-like" motion, although such embodiments are intended to be within the scope of the invention. For example, the moveable mirror layer may be anchored at its ends and may exhibit some curvature between the anchor points as it moves from one position to another. In addition, variances in resistance across the moveable mirror layer may result in one portion of the moveable mirror layer experiencing more movement than another portion. The invention is intended to encompass these embodiments within the definition of "piston-like" motion.

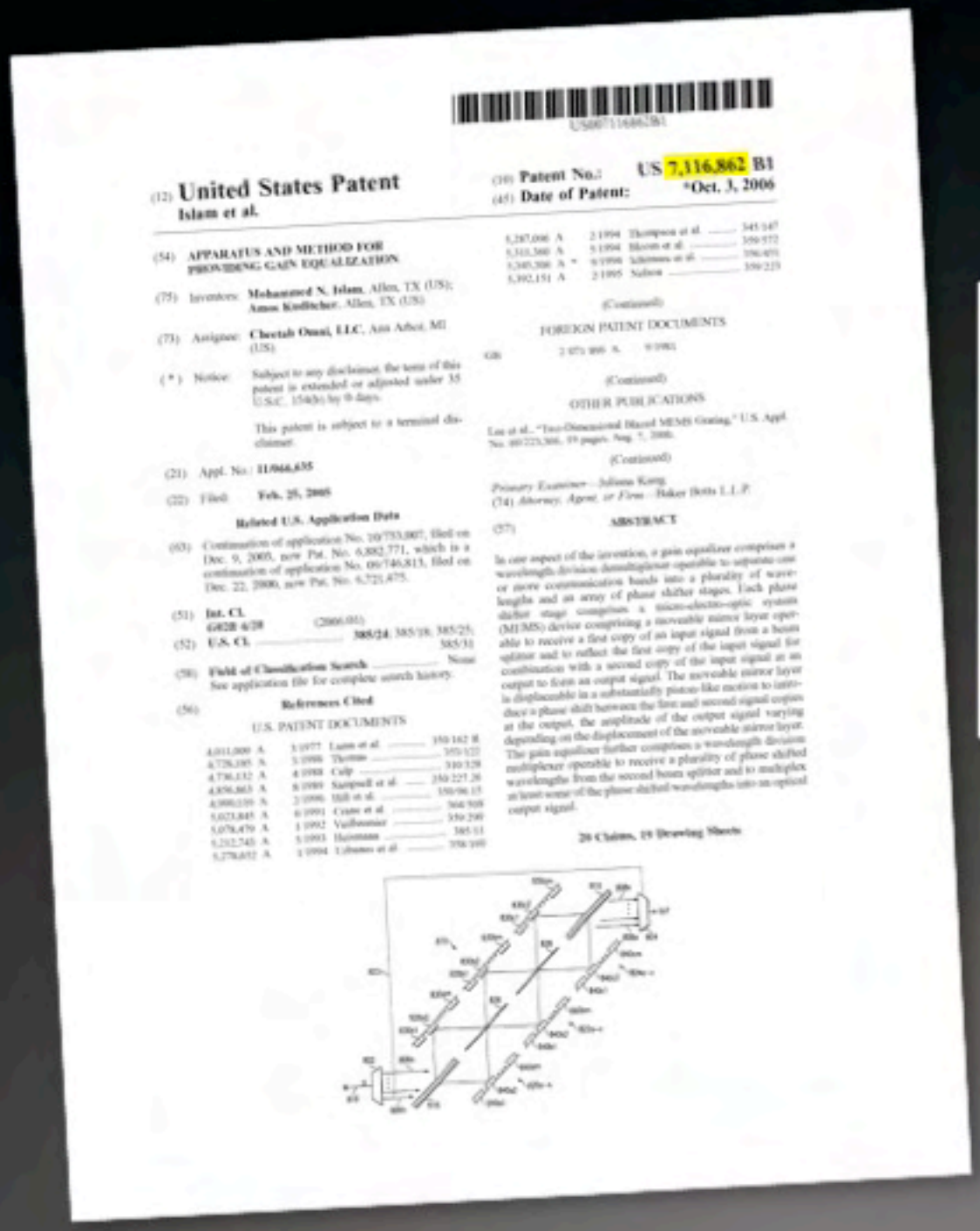
'862 Patent, col. 6 ll. 4-15.

Cheetah Argues that a Mirror Anchored at its Ends Cannot Move in "Piston-Like" Fashion

PLAINTIFF CHEETAH OMNI'S P.R. 4-5(c)
REPLY BRIEF ON CLAIM CONSTRUCTION

(Exhibit 2, col. 6, ll. 7-10.) Defendants do not explain how a mirror – "anchored at its ends" – can move "in an approximately parallel plane to the previous mirror position." Common sense confirms that it cannot. No object that is anchored at both ends can move in a plane parallel to its previous position. It can only move in an arc. Defendants' proposed construction simply does not cover the embodiments in the patent.

But the '862 Patent Says that a Mirror Anchored at its Ends Can Move in "Piston-Like" Fashion



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(12) **United States Patent**
Islam et al.

(10) **Patent No.: US 7,116,862 B1**
(45) **Date of Patent: *Oct. 3, 2006**

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20 Claims, 19 Drawing Sheets

For example, the moveable mirror layer may be anchored at its ends and may exhibit some curvature between the anchor points as it moves from one position to another. In addition, variances in resistance across the moveable mirror layer may result in one portion of the moveable mirror layer experiencing more movement than another portion. The invention is intended to encompass these embodiments within the definition of "piston-like" motion.

'862 Patent, col. 6 ll. 7-10.

The PTO Has Found that Claims Like '862 Claim 14 Require Piston-Like Motion

- Claims in the parent to the '862 patent have essentially the same wording as claim 14
- The examiner interpreted those claims to require piston-like motion
- Claim 14 should not be construed more broadly than the examiner's broadest reasonable construction

The PTO Has Found that Claims Like '862 Claim 14 Require Piston-Like Motion

7. Claims 6, 7, 12 and 13 are rejected under 35 U.S.C. 103(a) as being unpatentable over Riza as applied to claims 1 and 8 above, and further in view of Pilossof (US 2002/0021485).

limit the MEMs to a specific MEMs structure, it would have been obvious to one with ordinary skill in the art to use any type of MEMs that provides the piston-type action including Pilossof's MEMs structure for faster response.

The examiner believes claims 6, 7, 12, and 13 of the parent to the '862 patent require piston-type action.

Claim 14 Is Worded Similarly to Claims the Examiner Found to Require Piston-Like Motion

Claims in parent to '862 patent

wherein the moveable mirror layer comprises an at least substantially conductive structure operable to move relative to the inner conductive layer in response to a voltage difference between the moveable mirror layer and the inner conductive layer.

12. The method of Claim 8, wherein

wherein the moveable mirror layer comprises an at least substantially conductive structure operable to move relative to the inner conductive layer in response to a voltage difference between the moveable mirror layer and the inner conductive layer.

'862 claim 14

14. The method of claim **13**, wherein

wherein the moveable mirror is operable to move relative to the inner conductive layer in response to a voltage difference between the moveable mirror and the inner conductive layer.